

# **WIND POWERED IRRIGATION FOR SELECTED CROPS IN THE TEXAS PANHANDLE AND SOUTH PLAINS**

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## **ABSTRACT**

This paper examines the economics of farmers using wind energy to irrigate various crops in the Panhandle and South Plains of Texas. In this paper two cases were analyzed. The first case involved installing a new wind turbine, and the second case considered the installation of a used wind turbine from California. Both wind turbines would be connected to the irrigation motor and to the utility. When there is not enough wind to pump the water, utility electricity can be used. In order for wind energy to be economic for most farmers in the Texas Plains, the current net billing cap of 50 kW needs to be increased to at least 300 kW and preferably higher. The wind system becomes more economic if the farmer uses most of the wind generated electricity and only sells a small percentage back to the utility. Growing crops like winter wheat that match the wind resource can do this most effectively. We estimated that a farmer would reach payback in less than 10 years if he bought a wind turbine that matched the irrigation power requirements, and he also grew a crop like winter wheat. Since winter wheat needs no water during the summer, the utility may be willing to pay the farmer more money for wind generated electricity during the summer since this will reduce their peak generation. Using the wind energy for other agricultural activities like cotton ginning and grain drying which are performed during non summer months (low wind energy months) will also improve the economics of buying a wind turbine.

## **INTRODUCTION**

An in depth analysis of irrigation pumping systems was performed for the entire U.S. mainland to determine likely areas where wind, solar, or crop residue energy could be used to replace fossil fuels (Gilley, 1980; Lansford et al., 1980). One of the regions selected as promising for using wind energy for irrigation was the southern Great Plains. New et al. (1988) analyzed the irrigation pumping systems in the High Plains and Trans-Pecos areas of Texas in another study. While there have been many irrigation systems added since that time, the authors feel that the average size of the irrigation pumping systems are still approximately correct. These studies found that the average size pumping system in the North Texas Plains was 85 kW (115 hp) and for the South Texas Plains was 51 kW (68 hp). In previous testing with small wind-electric water pumping systems, it has been found that the wind turbine power rating should be 66 to 100% higher than that of the submersible motor power rating. This implies that the average wind turbine in the North Texas Plains should be 140-170 kW and in the South Texas Plains should be 85 – 100 kW.

The USDA-ARS Bushland facility has been investigating using wind energy for irrigation since the late 1970's. (Clark et al., 1980; 1981; and 1985). Tests were conducted with mechanical driven turbine pumps which were operated as stand-alone, mechanical-assist, and electrical-assist. Wind turbines and pumps were also connected to the utility grid. Recent investigations (Vick et al., 1997; Vick et al., 2000) for using wind energy for irrigating in the southern Great Plains

showed us that high water requirements for certain crops in July – August did not match well with the lower wind energy in those months. Because of the recent increase in natural gas prices, many farmers in the southern Great Plains who use natural gas powered water pumping systems have had to switch to dryland farming (no irrigation) and the accompanying lower yields (80% reduction). The farmers who currently use electricity for pumping water have also been affected because the utilities use natural gas-fired turbines.

We have examined four types of wind systems that can be used for irrigation:

- 1) Stand-alone electrical (e.g. not connected to utility)
- 2) Wind-diesel hybrid (e.g. also not connected to utility)
- 3) Directly connected to pump (e.g. all mechanical, no generation of electricity)
- 4) New or used wind turbine connected to utility

Currently the largest stand-alone wind turbine being manufactured is 10 kW, which is much too small for most irrigation applications in the southern Great Plains. A major problem with a stand-alone system is that some type of storage of water is necessary. For most irrigation applications only a few days of water storage is possible; otherwise, the water reservoir will have to be unreasonably large. To supply the water needed to irrigate corn in July and August on 259 ha (one section of land) in the Texas Panhandle in an average year would require a reservoir the size of 100 football fields with water 2 meters deep – this estimation doesn't even include evaporation loss. To the authors' knowledge there are no wind-diesel systems being used for irrigation because the cost is too high ( $> \$0.25/\text{kWh}$ ). Directly connecting a wind turbine shaft to an irrigation pump was investigated in the early 1980's. Results show that cut-in wind speed becomes excessive and wind turbine easily stalls in moderate wind speeds. The only wind system that we thought economical for irrigation was one intertied to the utility and that was the case investigated in this paper.

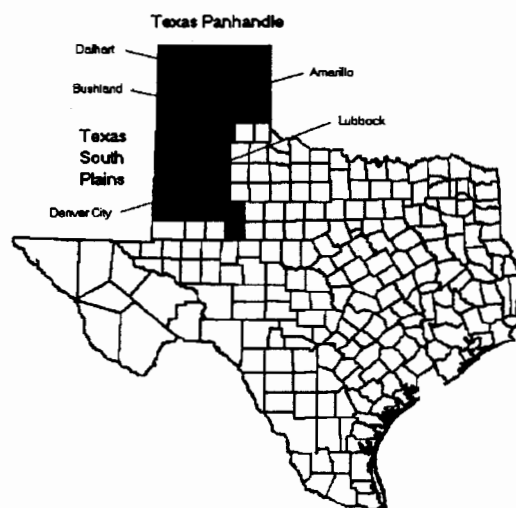
### **NET BILLING**

If a farmer is currently using electricity to pump irrigation water, a combination wind/utility system can be considered. The way the net billing rule currently exists in Texas is the wind turbine is connected to the utility through a single kilowatt-hour meter. At the end of the month if the consumer used more electricity than the wind turbine generated, the consumer will get a bill from the utility at the retail rate. If, however, the wind turbine has generated more power than was consumed, the utility will send the consumer a check for the electricity supplied at avoided cost. Avoided cost varies but the average rate for the local utility is  $\$0.025/\text{kWh}$ . In addition, if at the end of the year the consumer has not purchased a minimum amount from the utility ( $\$30/\text{hp}$  of the irrigation motor), the consumer is penalized this amount. Net billing allows the farmer to trade his wind-generated electricity with the utility at the retail rate. Net billing also enables the farmer to irrigate his land when the wind is not blowing and the farmer also does not have to install a costly water reservoir. Some states (California, Oregon, Rhode Island, Montana, New Jersey) have adopted annualized net billing instead of monthly net billing, which greatly improves the economics of buying a wind turbine for irrigating. There is an additional restriction that the rated capacity of the wind turbine cannot exceed 50 kW. This is a severe restriction for using wind energy for irrigation since it excludes most of the irrigation pumping systems in the Texas Plains. Unless the rated capacity limit is increased to 300 kW for the used wind turbine market and 1 to 2 MW in the new wind turbine market, there probably won't be much of a market for using wind turbines for irrigation. California increased their maximum rated capacity for a wind turbine to 1 MW for net billing, and New Jersey has no maximum rated capacity for a wind turbine. Since a 40 kW induction generator wind turbine was connected to an irrigation well from 1983 until present at the Bushland, TX USDA-ARS Laboratory (Clark et al., 1985), we had several years of actual data to determine the practicality and cost savings of a wind/utility system

approach. If the wind system can send power back to the utility during the fall and winter months (when not much irrigation water is needed) at the same rate the utilities are charging the farmer (i.e. retail rate); the wind system can pay for itself in 10 years. This payback assumes the cost of electricity is \$0.07/kWhr and a 1980 type American wind turbine is used. If the size of the wind system can be increased, the wind turbine/utility approach would result in an even quicker payback period. The analysis in this paper will assume the present Texas net billing rule except there won't be a limit to the size of the wind turbine for net billing.

## **TEXAS PLAINS WIND RESOURCE ADEQUACY FOR IRRIGATION**

Figure 1 shows the Texas Plains divided up into two regions by the Texas Agricultural Extension Service (TAES) – the Texas Panhandle and the Texas South Plains. The better wind resource area is the Texas Panhandle, which is evident from Figure 2. The wind energy at the 25 m height in Denver City is below the wind energy at Bushland at a 10 m height. Because the Bushland location is only 20 miles from the Amarillo location, the annual trend in wind energy at Bushland holds for the higher heights measured NE of Amarillo. Averaging the 1995, 1996, and 1997 Bushland data will give the same value as averaging the wind energy over 18 years, so the Amarillo data averaged over these three years was used in the analysis of irrigating in the Texas Panhandle. The low winds in Denver City for years 1996 and 1997 made it uneconomical to buy a wind turbine for irrigation in the South Plains. An incomplete dataset for Amarillo in 1998 resulted in using 50 m height Dalhart wind energy data for the monthly irrigation comparisons along with the 50 m height Denver City wind energy data (Figure 3). There are four major utility companies that provide electricity for irrigation in the Texas Panhandle and the Texas South Plains – Golden Spread Electric Coop<sup>1</sup>, Southwestern Public Service<sup>1</sup> (SPS), Lyntegar Electric Coop<sup>1</sup>, and the Lea County Electric Coop<sup>1</sup>. Golden Spread Electric Coop is made up of 11 different rural cooperatives distributed all over the Texas Panhandle and Texas South Plains, and provides about 80% of the electricity for irrigation. SPS provides electricity for irrigation in the Texas Panhandle, and Lyntegar and Lea County provide electricity for irrigation in the Texas South Plains.



**FIGURE 1. TEXAS PANHANDLE AND TEXAS SOUTH PLAINS.**

Figure 4 shows all the electrical energy that was used for irrigation and the wind energy available in the Texas Panhandle and Texas South Plains. These years (1997-2000) should be a good average since 1997 and 1999 had above average moisture and 1998 and 2000 were drought years. The first thing one notices in this graph is the peak electrical energy used for irrigation (August) occurs when the minimum wind energy is reached – e.g. a poor match of wind resource for

<sup>1</sup> The mention of trade or manufacture names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA – Agricultural Research Service.

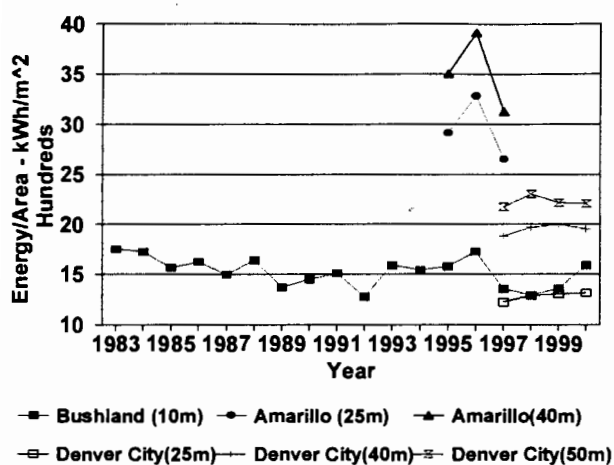


FIGURE 2. ANNUAL WIND ENERGY FOR LOCATIONS IN THE TEXAS PANHANDLE AND TEXAS SOUTH PLAINS.

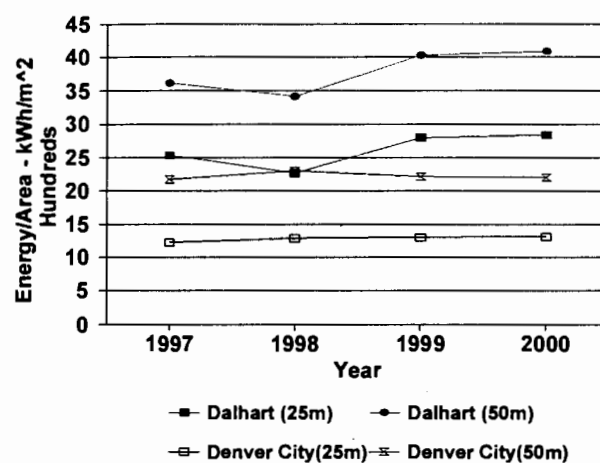


FIGURE 3. ANNUAL WIND ENERGY FOR DALHART (PANHANDLE) AND DENVER CITY (SOUTH PLAINS).

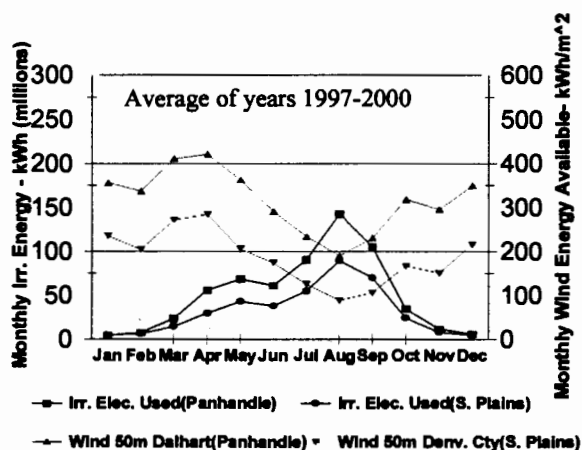


FIGURE 4. ELECTRICITY USED FOR IRRIGATION AND WIND ENERGY AVAILABLE IN TEXAS PANHANDLE AND TEXAS SOUTH PLAINS.

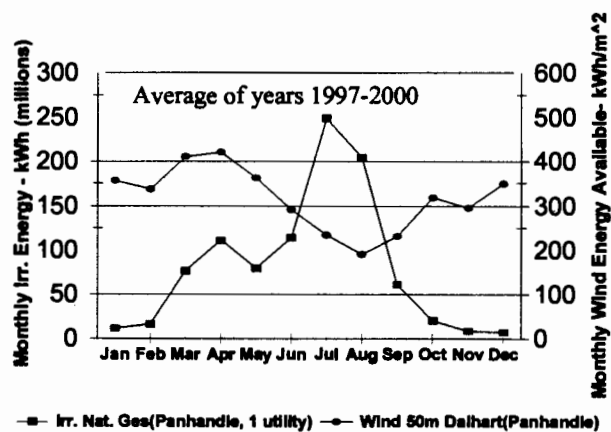


FIGURE 5. NATURAL GAS USED FOR IRRIGATION FOR ONE UTILITY AND WIND ENERGY AVAILABLE IN TEXAS PANHANDLE.

irrigation. In Figure 5, the natural gas usage matches the wind energy availability better since there is a relative maximum in the spring and the peak natural gas usage is in July. The relative maximum in the spring is due to more winter wheat being grown, and the July maximum peak reflects more corn than sorghum.<sup>2</sup> The monthly trends in wind energy and irrigation use are very similar for both the Texas Panhandle and Texas South Plains. Figures 6 and 7 show the land area irrigated for crops grown in the Panhandle and the South Plains. These numbers were obtained from the Texas Agricultural Statistics Service (TASS) who has a few counties different in its districts than the TAES but trends should be about the same. Corn, cotton, and wheat are the major crops irrigated in the Panhandle while cotton and peanuts are the major crops irrigated in the South Plains. Although not much wheat is irrigated in the South Plains, it is the third largest crop irrigated. Figures 8 and 9 show the average amount of irrigation water needed for the three main irrigated crops in the Panhandle and the South Plains plus the wind energy available. The rainfall assumed for the Panhandle was the 20 year average of Amarillo and rainfall assumed for the South Plains was the 20 year average of Lubbock. While corn is better than cotton and peanuts for matching the wind resource, wheat is almost a perfect match for the wind resource in both the Panhandle and the South Plains. Figure 10 shows the past ten years of commodity prices in Texas. Since there is no progressively increasing price of any commodity with time, the margins for using single wind turbines for irrigation in the Panhandle will be very tight.

Figure 11 shows how cotton ginning in both the Panhandle and South Plains would provide an electrical load in the fall for the wind turbine if the farmer is raising corn, cotton, or sorghum. Although both natural gas and electricity can be used to gin cotton, the average amount of energy needed to gin a bale of cotton is 50 kWh. Using this number plus the amount of bales ginned each month, the electrical loading for cotton was determined. Other electrical loads for the wind turbine during higher wind months include grain drying and hog farm operation although no numbers were obtained for these operations. Since cotton ginning and most grain drying are done at cotton gins and grain elevators, having the net billing rule cover this wind generated electricity would require an agreement between the farmer, cotton gin/grain elevator, and utility.

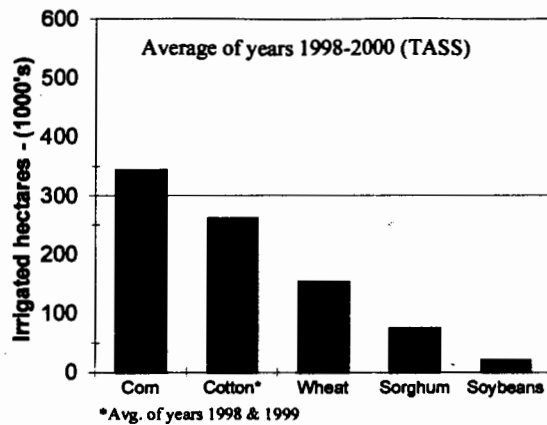
### **NEW WIND TURBINE ANALYSIS**

In order to determine whether buying a new wind turbine and installing it for irrigation was economically feasible, a farmer farming several sections of land in the north part of the Panhandle was selected. He supplied us with his monthly natural gas bills during the year 2000, and I used the multiplier 75.3 kWh/MCF to convert to kWh. Since there was very little rain during July, August, and September, the amount of irrigation water needed was greater than average. Several assumptions needed to be made to do the economic analysis of purchasing a wind turbine for irrigation and they were:

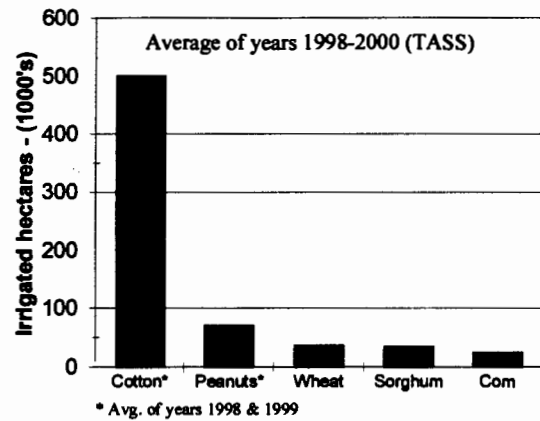
1. Cost of installed wind turbine = \$415/m<sup>2</sup>
2. 40 m to 65 m hub height – depending on wind turbine tower availability
3. O&M cost = 0.01 \* (kWh generated)
4. 95% availability
5. Could obtain 10% return on money used to buy wind turbine
6. Get capacity restriction on Texas net billing rule raised from 50 kW to 2 MW
7. Monthly net electricity to utility = \$0.025/kWh

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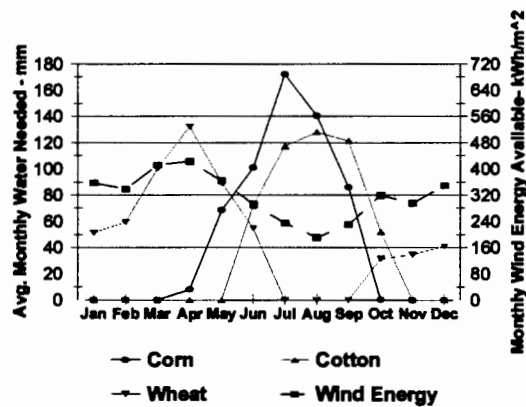
<sup>2</sup> Leon New of TAES determined that 1 MCF (1000 cubic feet) of natural gas equates to 75.3 kWh including the change in engine and electric motor efficiencies. Using that number the monthly MCF was converted to kWh.



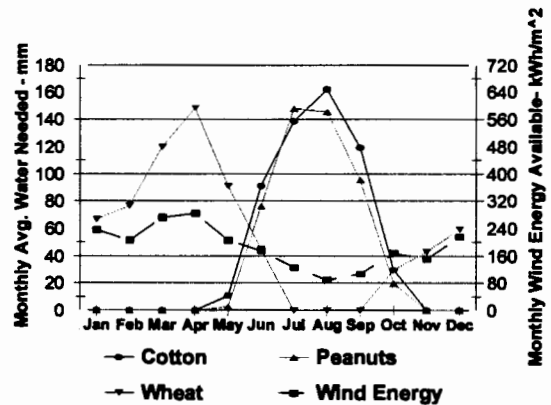
**FIGURE 6. AMOUNT OF IRRIGATED LAND FOR CROPS IN THE TEXAS PANHANDLE.**



**FIGURE 7. AMOUNT OF IRRIGATED LAND FOR CROPS IN THE TEXAS SOUTH PLAINS.**



**FIGURE 8. IRRIGATION WATER NEEDED AND WIND ENERGY AVAILABLE FOR TEXAS PANHANDLE.**



**FIGURE 9. IRRIGATION WATER NEEDED AND WIND ENERGY AVAILABLE FOR TEXAS SOUTH PLAINS.**

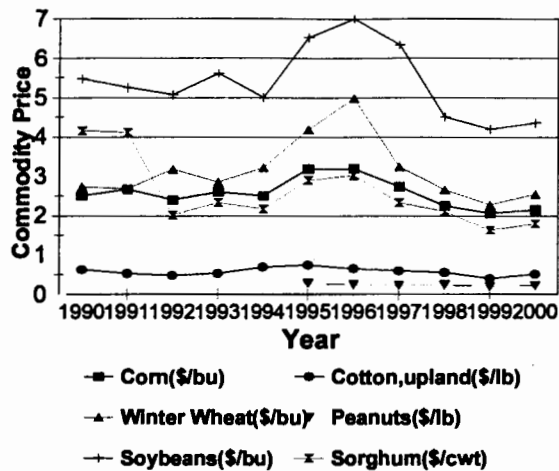


FIGURE 10. HISTORICAL TREND OF CROP PRICES (TEXAS).

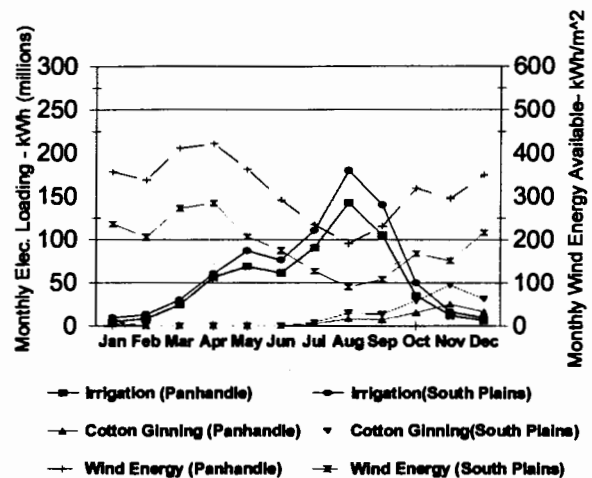
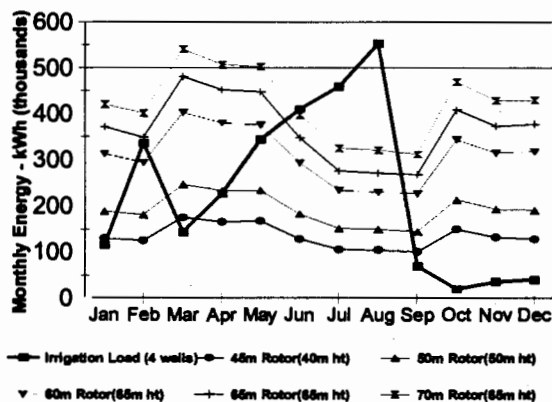
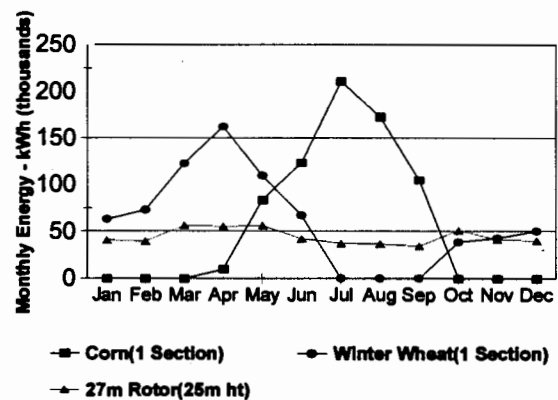


FIGURE 11. INCLUDING COTTON GINNING AS AN ADDITIONAL ELECTRICAL LOAD FOR WIND GENERATED ELECTRICITY.



Note: Northern Texas Panhandle Farm (year 2000)

FIGURE 12. COMPARISON OF IRRIGATION NEEDED TO WIND TURBINE ENERGY SUPPLIED.



Note: Texas Panhandle

FIGURE 13. IRRIGATION ENERGY NEEDED FOR TWO CROPS AND WIND TURBINE (USED) ENERGY SUPPLIED.

The cost of installing a single wind turbine for each wind turbine manufacturer was difficult to obtain. However, costs of a recent large wind turbine that was installed in the area were obtained and the amount of dollars per square meter of rotor swept area came out to \$415/m<sup>2</sup>. Using this number the costs of the other wind turbines were determined. One cost which wasn't included was the cost of a transformer to convert the higher voltage of the wind turbine to 480 V (irrigation motor voltage). Power curves were obtained from several different wind turbine manufacturers and power curves of similar rotor diameters were averaged. The wind data used was from a site NE of Amarillo where 10 m, 25 m, and 40 m height wind data were recorded from 1995 to 1997.

Figure 12 shows the irrigation energy needed on the farm and the wind turbine energy that could be supplied by different size wind turbines. It will be noticed that a relative maximum occurs in February and this is due to some winter wheat that was planted. The reason no 55 m rotor is shown is due to the spreadsheet program only allowing six curves. Rather than pick the current utility cost, it was decided to do a range of utility costs/kWh. Table 1 shows the payback in years for various rotor diameters for utility costs of \$0.10 and \$0.15 per kWh. While the short payback period for \$0.15/kWh may look good, the commodity prices of the crops would have to increase significantly before a farmer could afford that irrigation cost. Of course if the farmer had grown all winter wheat, the payback period would have been much shorter provided prices are higher for winter wheat.

**TABLE 1**  
**NEW WIND TURBINE ANALYSIS**  
**CROPS GROWN (33% CORN, 16% SORGHUM, 16% SOYBEANS,**  
**AND 33% WINTER WHEAT)**

	<b>Rotor Dia.</b>	<b>Cost of W.T. Wind Turbine</b>	<b>20 year Lifetime Savings</b>	<b>Payback</b>
<b>UC = \$0.10</b>				
	45 m	\$0.66 million	\$1.44 million	13.2 years
	50 m	\$0.82 million	\$2.06 million	11.7 years
	55 m	\$0.99 million	\$2.43 million	12.0 years
	60 m	\$1.17 million	\$2.70 million	12.7 years
	65 m	\$1.38 million	\$2.18 million	16.4 years
	70 m	\$1.60 million	\$1.76 million	19.3 years
<b>UC = \$0.15</b>				
	45 m	\$0.66 million	\$6.12 million	2.65 years
	50 m	\$0.82 million	\$7.10 million	2.90 years
	55 m	\$0.99 million	\$7.87 million	3.20 years
	60 m	\$1.17 million	\$8.50 million	3.60 years
	65 m	\$1.38 million	\$9.11 million	4.00 years
	70 m	\$1.60 million	\$9.23 million	4.70 years

#### **USED WIND TURBINE ANALYSIS**

For the used wind turbine analysis we wanted to pick a wind turbine which would approximate the size wind turbine which would power the average size motor determined by New et al., 1988. A 27 m rotor wind turbine should provide the energy required to power a 85 kW (115 hp) motor. We also decided to see the effect of irrigating a crop like corn which needs most of its water in the summer compared to a crop like winter wheat whose maximum water usage occurs in the

spring (wind resource is also maximum in spring). Several assumptions had to be made again for purchasing a used wind turbine for irrigation and they were:

1. Installed 27 m/225 kW wind turbine from California (\$500/kW = \$112,000)
2. 25 m hub height
3. Shipping from California to Texas
4. O&M cost = .02 \* (kWh generated)
5. 90% availability
6. Could obtain 10% return on money used to buy and install wind turbine
7. Get cap raised to 300 kW on Texas net billing rule
8. Monthly net electricity to utility = \$0.025/kWh

Since USDA-ARS and Sandia Labs has bought 4 used Micon 65's from California, and installed them in Bushland, TX, the \$500/kW estimate appears to be about right. Of course the O&M cost will increase and the availability will decrease on a used wind turbine, but the difficult part is figuring how much. We assumed the O&M cost and down time on the wind turbines would double. If the O&M cost was significantly higher or the availability was significantly lower, the used wind turbine would no longer be economic. Figure 13 shows the irrigation energy required for corn and winter wheat and the amount of energy supplied by the wind turbine.<sup>3</sup> Table 2 shows the payback and 20 year lifetime savings for corn and winter wheat at a utility cost of \$0.05, \$0.10, and \$0.15 per kWh. Obviously growing winter wheat is preferable over growing corn if a wind turbine is purchased. Since the utility is always trying to reduce their peak during the summer, growing winter wheat will result in selling all the electricity generated by the wind turbine during the summer to the utility. The utility may be willing to buy the wind generated electricity at a price greater than avoided. Therefore, it's a win/win situation for the farmer and the utility. Even if corn was grown, the utility would not have to supply the electricity during the summer that the wind turbine is providing.

**TABLE 2**  
**USED WIND TURBINE ANALYSIS**

	Utility Cost	Payback	20 year Lifetime Savings
<b>Corn</b>			
	\$0.05	33.7 year	-----
	\$0.10	7.9 year	\$ 418,039
	\$0.15	4.5 year	\$ 672,761
<b>Winter Wheat</b>			
	\$0.05	13.7 year	\$ 233,740
	\$0.10	3.9 year	\$ 753,536
	\$0.15	2.3 year	\$1,181,742

<sup>3</sup> Leon New at TAES also determined that for a 85 kW (115 hp) irrigation motor, 1 ha cm = 60 kWh (1 Ac in = 62 kWh). This multiplier was used to calculate the amount of energy to water 1 section of corn and wheat.

## **CONCLUSIONS**

If the cost of the utility supplied electricity is \$0.10 to \$0.15 and the commodity price is high enough, installing a new wind turbine (45 to 70 m rotor diameter) or a used wind turbine (27 m rotor diameter) will save money which requires increasing the cap on the net billing rule. If the farmer switches to a crop which matches the wind resource well and also needs to be irrigated, the farmer in the Texas Panhandle will have a payback between 4 and 14 years if the cost of the utility electricity is between \$0.05 to \$0.10 per kWh. If a crop like corn or cotton is chosen which requires much water in summer but little in the other months, the wind turbine will still be a good investment if other farm electrical loadings are found for the wind turbine during the fall, winter, and spring. We didn't have enough time to analyze using a wind turbine in the South Plains for this paper. However, the low wind speeds (compared to the Panhandle) of the lower South Plains make the purchase of a wind turbine – new or used probably uneconomical.

## **ACKNOWLEDGMENTS**

We would like to thank Ken Starcher (AEI<sup>1</sup>) for supplying us with data and information to analyze using wind turbines for irrigation. We would also like to thank Kelley Grimes (Energas<sup>1</sup>), Greg Boggs (XCEL Energy<sup>1</sup>), Mike Faris (Lea County Electrical Coop), Greg Henley (Lyntegar Electrical Coop), Kathleen Best (Consultant), and Dorothy Pierce (C.H. Guernsey & Co.<sup>1</sup>) on supplying the monthly energy data for irrigation in the Texas Plains. We would also like to thank Leon New (TAES) and Arland Schneider (USDA-ARS) for help on irrigation issues.

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